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COVER SHEET FOR TECHNICAL MEMORANDUM

TITLE- Transmission of Bulk Experiment
Data from Skylab to the MSFN

TM-70-2034-7

DATE- July 2, 1970

FILING CASE NO(S)- 900

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ABSTRACT

The telemetry receiving capabilities of several MSFN configurations are examined for their utility of receiving bulk experiment data from the Skylab B missions. The MSFN configurations examined are: (1) the presently planned Skylab MSFN of 12 stations without major modifications, (2) adding a direct relay capability to Skylab over Intelsat IV satellites in addition to the 12 station MSFN, and (3) adding the ERTS receiving station at GSFC (NTTF) to the 12 station MSFN and also modifying the Goldstone station with an ERTS type of receiving capability.

The results show that the Skylab MSFN without major modifications could, by onboard recording and dump, receive (1) data generated by 5 of the 6 Skylab experiments considered as well as operational data on one link, or (2) data generated by 4 of 6 experiments plus operational data on two links. The MSFN with the addition of Intelsat IV used for direct relay of one operational data link could receive data from all 6 experiments or from 5 experiments plus a second operational link. The MSFN modified by installing ERTS receiving capability at the NTTF and the Goldstone station would support all six experiments by dumping recorded data to these two stations alone.

The transmission of the experiment data to the MSFN over radio links would markedly reduce the amount of films and magnetic tape, that would need to be brought back by the CSM and represents a potential return weight saving of 440 to 600 lbs. in the CSM payload depending on the particular MSFN configuration chosen.

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TECHNICAL MEMORANDUM

I. INTRODUCTION

In the planning of Skylab B mission, there is a possibility that the weight of film and magnetic tape containing experiment data may exceed the return CSM control weight allotted to them. A method of alleviating this problem is to transfer the data from Skylab spacecraft to the ground by the use of telemetry links. This memorandum examines the receiving capabilities of three different receiving network configurations:

1. Skylab MSFN using 12 ground stations without major modifications,
2. Skylab MSFN plus the use of Intelsat IV satellites for the direct relay of voice and data between Skylab and the U. S., and
3. Skylab MSFN with two stations modified for Earth Resources Technology Satellite (ERTS) type of receiving capability.

The emphasis of this memorandum is the receiving capability of the ground network; no attempt is made to analyze fully the implementation of the Skylab spacecraft facilities to match the ground receiving capability. Effectively, the information provided here is an input, from the ground network support viewpoint, to the planning and design of a complete end-to-end system. Many iterations can be expected in order to arrive at a desirable and practicable ground support system for the Skylab B mission.

Section II is a summary and discussion of the proposed experiments for Skylab B that can be classified as bulk data generators which results in their use of large amounts of film and magnetic tape. Section III provides the MSFN coverage for

Skylab missions using a 12 station configuration (three 85 ft. antenna stations and nine 30 ft. antenna stations including Santiago). The present and projected implementation of the Skylab MSFN stations are presented in Section IV, which also defines the capability of these stations to receive the experiment data from Skylab. Section V is a discussion of the use of Intelsat IV satellites as a direct relay for Skylab missions. The capacity of the relay link and the corresponding relay terminal design on the Skylab spacecraft is based on a Hughes Aircraft Company study done for NASA. The payloads for ERTS and the proposed ground receiving station, (in particular, the modifications of MSFN for ERTS) are summarized in Section VI with a discussion of the use of ERTS-type of receiving station modification for Skylab missions. In Section VII a match is made between the various network options and the experiment data requirements of Skylab II. These are given as examples of "what the network can do" without considering the attendant implementation requirements onboard the Skylab. A summary is provided in Section VIII.

II. PROPOSED SKYLAB II EXPERIMENTS

The three major categories of experiments proposed for Skylab B are: (1) Solar Telescope (ATM-B), (2) Earth Resources, and (3) Artificial gravity. The bulk data are generated by the experiments in the first two categories. A breakdown of the individual experiments proposed is shown in Tables 1 and 2. (1) Data from seven of these experiments could be recorded either on film or magnetic tape which would come under the allotted control return weight of the CSM. The reader should be aware that the definition and the requirements in the experiment area for the Skylab B mission is uncertain at this time. Changes are made frequently during the current proposal and system sizing stage. We will see discrepancies in return film weight, data generating rate, and bandwidth requirements between Tables in this memorandum. This is unavoidable as the information is gathered on a daily basis from various sources; the data within the same table, however, is self-consistent.

From these seven experiments, six of them are selected for more detailed examination. The experiment omitted is the Support Telescope (Observation and Sampling Telescope) with a film

1. From Skylab II I&C Study Group, Minutes of Meeting on May 18, 1970, at MSFC.

TABLE 1
ATM-B EXPERIMENTS DATA SUMMARY

EXPERIMENT	DATA		FILM WEIGHT PER 90 DAYS (lbs)
	SCIENTIFIC (bps)	HOUSEKEEPING (bps)	
PHOTOHELIOGRAPH	400	1100	135
X-RAY SPECTROHELIOGRAPH	1410	5205	45
UV SCANNING POLY- CHROMATOR SPECTROHELIOMETER	4656	3621	0
HYDROGEN-ALPHA TELESCOPE	0	72	0

TABLE 2

SUMMARY OF EARTH RESOURCES EXPERIMENT DATA RETURN REQUIREMENTS

SENSOR	DATA-TAKING		CM RETURN REQ'D		T/M
	TIME 90 DAY (MIN)	WT/UNIT (LBS)	90 DAY FLIGHT (LBS)	REQUIREMENT	
IR SPECTROMETER (S191)	60	SHARE TIME		YES	
10 BAND MULTISPECTRAL SCANNER (S192)	810	12/14" REEL	200	SELECTED	
MULTIFREQUENCY MICRO- WAVE RADIOMETER	1335	SHARE TIME		YES	
PASSIVE MICROWAVE IMAGER	1000	SHARE TIME		YES	
MULTISPECTRAL PHOTOGRAPHY (S-190)	892	2/CASSETTE	36	NO	
METRIC CAMERA	892	38/CASSETTE PAIR	38	NO	
RADAR IMAGER	1000	20/CASSETTE	120	NO	
TELESCOPE (SUPPORT CAMERA)	UNLIMITED	1.5/CASSETTE	100	NO	

return weight of 100 lbs. The objective of this experiment is to allow the crew taking pictures of special interest during the mission similar to what a tourist would do. By nature, the amount of data taken and the data generating rate will be unplanned and unpredictable, therefore, the supporting telescope experiment data is excluded from the analysis.

Tables 3, 4, and 5 provide estimates of the amount of experiment data and the data generating rates of two solar astronomy and four earth resources experiments. Tables 3 and 5 assume that the film and magnetic tape data could be processed on-board into digital format for transmission, and Table 4 assumes that vidicon and video recorder systems are used to provide the same resolution and the same format as the films. It is noted on Table 4 that 8200 and 23000 scan line systems needed for the Earth Resources experiments are not available at the present time. If one examines the resolution requirements for these experiments (50 and 35 line-pairs/mm), however, a vidicon system proposed for the Earth Resources Technology Satellite (ERTS) could be considered. This particular system would have a resolution of 80 line-pairs/mm on a 1"x1" format using 4000 scan lines⁽²⁾. Therefore, the use of such a vidicon system would require more frames to be taken for the same coverage area on earth, as the format sizes planned for the films are about 2 1/4" x 2 1/4" and 9" x 13 1/2" as shown on Table 3. The frame/day and bits/day numbers shown on Tables 3 and 5 are average numbers for a 90 day mission; depending on the target opportunities and the experiment management, the data generated on a day-by-day basis could fluctuate. Also, the bit/sec (continuous) numbers are intended to provide a more familiar parameter for comparison purpose; it is not an endorsement that the data should be sent back on a continuous (86,400 seconds per day) basis.

It is also interesting to note the ratio of bit/sec and the return weight on Tables 3 and 5. It is obvious that the weight per bit varies considerably for the experiments, and therefore, it would be advantageous to choose the higher weight/bit experiment data as the candidates for transferring the data by radio means instead of carrying back the film or magnetic tape. These experiments are the X-ray spectroheliograph, photoheliograph, and 10-band multispectral scanner assembly.

2. H. M. Gurk, "Television Systems for Earth Resources Satellite", presented at The British Interplanetary Society International Summer School on Earth Resources Survey Satellites, July, 1969.

TABLE 3

FILM DATA GENERATION RATE -- DIGITAL TRANSMISSION

	SOLAR ASTRONOMY			EARTH RESOURCES		
	SPECTROHELIOGRAPH	X-RAY	PHOTO- HELIOGRAPH	MULTISPECTRAL PHOTOGRAPHY	METRIC CAMERA	RADAR IMAGER
NO. OF CAMERAS	1		3	6	2	1
FRAME FORMAT (MM)	18 X 18		21 X 21	57 X 57	230 X 360 (57 X 57)*	?
RESOLUTION (LINE-PAIR/MM)	10		30	50	35, (40)	?
ELEMENTS/FRAME	1.3 X 10 ⁵		1.6 X 10 ⁶	3.25 X 10 ⁷	4 X 10 ⁸ (2.08 X 10 ⁷)	?
BITS/ELEMENT (ASSUMED)	6		6	6	6	1
BITS/FRAME	7.8 X 10 ⁵		9.6 X 10 ⁶	2 X 10 ⁸	2.4 X 10 ⁹ (1.2 X 10 ⁸)	?
FRAME/90 DAY	2.14 X 10 ⁴		1.95 X 10 ⁵	9 X 10 ³	3000	?
DATA PERIOD/DAY	4 X 26 MIN		4 X 20 MIN	2 X 10 MIN	2 X 10 MIN	2 X 10 MIN
FRAME/DAY	286		2600	720	2 X 40	?
BITS/DAY	2.2 X 10 ⁸		2.6 X 10 ¹⁰	1.44 X 10 ¹¹	10 ¹¹	1.6 X 10 ¹⁰ †
BIT/SEC (CONTINUOUS)	2.6 KBPS		300 KBPS	1.67 MBPS	1.16 MBPS	185KBPS†
FILM RETURN WEIGHT	45 LBS		135 LBS	36 LBS	66 LBS	60-120 LBS

*STELLAR CAMERA

†BASED ON 200 MIN OF DATA DURING A 75-DAY PERIOD OF A 90 DAY MISSION WITH A DATA GENERATION RATE OF 10⁸ BIT/SEC

TABLE 4
ALTERNATIVE TELEVISION TRANSMISSION SYSTEM PARAMETERS

	SOLAR ASTRONOMY		EARTH RESOURCES	
	<u>SPECTROHELIOGRAPH</u>	<u>PHOTO- HELIOGRAPH</u>	<u>MULTISPECTRAL PHOTOGRAPHY</u>	<u>METRIC CAMERA</u>
NO. OF CAMERA	1	3	6	2
TV SCAN LINES/FRAME	512	1800	8200	23,000 (6500)*
ASPECT RATIO	1	1	1	1.5, (1)*
FRAME/SEC	1 (5%), 1/30 (95%)	1 (10%), 1/10 (90%)	1/8, 1/18	1/30
VIDEO BANDWIDTH/SYSTEM				
SLOW RATE	3.2 KHz	1.13 MHz	1.3 MHz	500 KHz
FAST RATE	100 KHz	3.4 MHz	3 MHz	10 MHz
FRAME/DAY	286	2600	720	2 X 40
			VIDICON TECHNOLOGY NOT AVAILABLE	

*STELLAR CAMERA

TABLE 5
DIGITAL TRANSMISSION OF EARTH RESOURCES DATA
10-BAND MULTISPECTRAL SCANNER ASSEMBLY (S-192)

NO. OF CHANNELS	22	1
BIT RATE/CHANNEL	1.2 MBPS	∞
DATA PERIOD/DAY	TWO 5 MIN PERIODS	1
TOTAL BITS/DAY	1.6×10^{10}	
BIT/SEC IF SENT CONTINUOUSLY THROUGHOUT A DAY	185 KBPS	
TAPE RETURN WEIGHT	200 LBS	

III. SKYLAB MSFN COVERAGE

Computer runs were made using the Bellcomm ALTER I program⁽³⁾ to determine the Manned Space Flight Network (MSFN) coverage provided by the 12 stations listed in Table 6 with their coordinates. All contacts ≥ 3 minutes were printed out in addition to the gap time between these contacts. The results were plotted in Table 7 for a period of 156 revolutions (approximately 10.8 days) after which the coverage closely repeats itself, i.e. coverage for Revolution (1), (157), and (313), are about the same. The parameters used for this mission were: an altitude of 235 n.m., an orbital plane inclination angle of 50° , and a uniform masking angle about each MSFN station of 3° with appropriate antenna keyholes.

Data was started at the insertion point. Table 7 shows the coverage provided and the size of the gaps in minutes between contacts. Canary Islands (CYI) appears twice in the column headings since sometimes its contact comes sometimes before and sometimes after Ascension Island depending on the sub-vehicle track of the spacecraft. Those contacts of 3 minutes duration or greater, but less than 6 minutes, are shown with a heavy line border. Contacts this size may be used for voice communication but are not of sufficient duration for data dump. A contact must be 6 minutes or greater to provide enough continuous contact for a good data dump. A summary is shown on each table of the maximum gap time for 2 days, the total number of contacts, number of contacts greater than 6 minutes, the total contact time and contact time consisting of contacts greater than 6 minutes. Although the exact coverage time varies from day to day, on the average these 12 stations provide approximately 300 minutes/day of coverage time consisting of contacts larger than 6 minutes. The overlapping contacts that occur among the complex of GDS, TEX, MIL, and BDA and the combination of CYI and MAD appear to be well suited for television transmissions. These transmissions can be used for public affairs office purposes as well as for ground monitoring of solar astronomy experiments. Overlapping contacts occur at more or less periodic intervals for durations ranging from 7.4 minutes to 15.6 minutes.

3. H. Pinckernell, "A Computer Program to Compute Space Vehicle Contact Time, Slant, Range, and Altitude", Bellcomm Memorandum for File, December 8, 1964.

TABLE 6

MSFN STATIONS AND THEIR COORDINATES

STATION NAME AND SYMBOL	LONGITUDE (DEGREES EAST)	LATITUDE (DEGREES)
1. CAPE KENNEDY (MIL)	274.3066	28.5083N
2. SANTIAGO (SAN)	290.0000	33.0000S
3. BERMUDA (BDA)	295.3419	32.2506N
4. CANARY ISLANDS (CYI)	344.3653	27.7644N
5. ASCENSION (ACN)	345.6728	7.9547S
6. MADRID (MAD)	355.8306	40.4550N
7. CARNARVON (CRO)	113.7255	24.9066S
8. GUAM (GWM)	144.7369	13.3106N
9. HONEYSUCKLE (HSK)	148.9783	35.5837S
10. HAWAII (HAW)	200.3344	22.1264N
11. GOLDSTONE (GDS)	243.1267	35.3417N
12. TEXAS (TEX)	262.6217	27.6539N

TABLE 7
MSFN COVERAGE FOR SKYLAB (235 NM ALTITUDE, 50° INCLINATION) (3° MASKING)

REV	CRO	GWM	HSK	HAW	GDS	TEX	MIL	BDA	SAN	CYI	ACN	CVI	MAD
1						START OF DATA		4.1					7.8
1	57.6	4.1	27.4			12.0							8.9
2	36.3	6.9	22.8					14.0				8.5	
3	36.0	8.8	17.5	8.8	2.0	6.7		8.5	6.5	7.7	6.9	9.7	
4	33.0	4.5	16.5	4.2	2.4	4.5	9.5		8.7		7.3	9.7	
5	8.8	4.4	8.7			15.7						9.0	
6						13.4		10.2	5.6				
7						14.3		14.3	8.8				
8				7.0		20.7		20.7	5.8				
9				8.1									
10				17.5					4.1	9.7	8.7		
11	55.3	8.3				14.2		14.2	8.4				12.2
12	25.9	5.3	6.0	5.0		21.6		21.6	7.7				12.3
13	3.0	1.6		8.8		14.9		14.9					7.2
14	8.8	1.2		6.3			12.8						7.6
15	3.1	5.7		4.1		13.9							8.8
16	30.7		6.2			8.7			7.5			8.0	
17	30.4		8.7	11.8	8.5	6.4	4.4		3.9	7.7	5.2		
18	32.9		5.2	14.4	6.1	5.7	8.6		8.4		8.2	5.7	
19	8.5	4.8	8.4			16.4					23.4		
20	5.7	8.0	5.3			14.2							
21									8.8				
22				5.4		13.6			6.7				
23				8.6		20.9							
24									13.6				
25													
26									7.9	5.7	4.8	11.3	
27	34.5		8.8			15.7			8.3				
28	8.7	1.4		30.8			12.0						6.9
29	5.3	4.3	4.4	27.8		14.3							7.4
30													8.6

LEGEND:
 12.0 CONTACT TIME > 6 MIN
 3.3 CONTACT TIME < 6 MIN
 OUT OF CONTACT TIME
 IN MINUTES

SUMMARY FOR 1ST & 2ND DAYS:
 MAX GAP TIME = 134.6 MIN (BETWEEN ALL CONTACTS AND BETWEEN 6 MIN CONTACTS)
 TOTAL NO. OF CONTACTS = 93
 NO. OF CONTACTS > 6 MIN = 64
 TOTAL CONTACT TIME = 700.0 MIN
 CONTACT TIME > 6 MIN = 568.9 MIN

LAST CONTACT OF 2ND DAY

TABLE 7 (CONT'D)
MSFN COVERAGE FOR SKYLAB (235 NM ALTITUDE, 50° INCLINATION) (3° MASKING)

REV	CRO	GWM	HSK	HAW	GDS	TEX	MIL	BDA	SAN	CYI	ACN	CYI	MAD
29							14.3						3.6
30	5.6	5.6	5.6	5.6	5.6	9.3							7.4
31	8.5	8.5	8.5	8.5	8.5	6.2				8.4			
32	5.8	5.8	5.8	5.8	5.8	4.4					8.7		
33	8.0	8.0	8.0	8.0	8.0	5.0	11.1						
34	7.2	7.2	7.2	7.2	7.2		15.0						
35						10.8			8.6				
36									7.4				
37													
38													
39	6.1	6.1	6.1	6.1	6.1				7.3				9.2
40	8.1	8.1	8.1	8.1	8.1				8.7				12.9
41													
42	8.4	8.4	8.4	8.4	8.4								6.7
43	6.7	6.7	6.7	6.7	6.7								7.3
44													8.4
45													7.9
46													
47	7.3	7.3	7.3	7.3	7.3								
48	8.1	8.1	8.1	8.1	8.1								
49													
50													
51													
52													
53	3.8	3.8	3.8	3.8	3.8								3.4
54	8.6	8.6	8.6	8.6	8.6								
55													
56													
57	7.7	7.7	7.7	7.7	7.7								8.2
58	4.5	4.5	4.5	4.5	4.5								8.8

SUMMARY FOR 3RD & 4TH DAYS:
MAX GAP TIME = 134.8 MIN (INCLUDING CONTACTS ≥ 3 MIN)
= 135.6 MIN (BETWEEN CONTACTS ≥ 6 MIN)

LEGEND:
12.0 CONTACT TIME ~ 6 MIN
3.3 CONTACT TIME ~ 6 MIN
OUT OF CONTACT TIME IN MINUTES

TOTAL NO. OF CONTACTS > 6 MIN = 89
NO. OF CONTACTS > 6 MIN = 74
TOTAL CONTACT TIME = 712.6 MIN
CONTACT TIME > 6 MIN = 645.0 MIN

LAST CONTACT OF 4TH DAY

TABLE 7 (CONT'D)
MSFN COVERAGE FOR SKYLAB (235 NM ALTITUDE, 50° INCLINATION) (3° MASKING)

REV	CRO	GMM	HSK	HAW	GDS	TEX	MIL	BDA	SAN	CYI	ACN	CYI	MAD
58	5.7	7.7	4.6	4.9	9.4					12.1			8.8
59	5.6	7.7	4.6	4.9	8.5					11.9			8.8
60	5.1	8.7	7.1	8.5	5.6		5.9	6.9		9.3	8.4		23.5
61	8.6	3.5			4.0	13.1	10.0			10.0	4.6		24.4
62	8.6	4.6	8.5			15.6							
63						12.8		9.6	7.5				
64									8.4				
65				8.2			21.1		4.3				
66				6.4			40.9				3.4		
67									5.6	6.0			33.4
68						30.2			8.7				12.8
69						23.1			5.9				11.3
70	6.6	0.2											23.9
71	8.3	1.6					14.1						7.3
72													26.6
73													7.9
74													8.9
75													
76	8.8	4.4	8.7										8.6
77						13.2							
78						4.6							
79						7.5							
80						7.8							
81													
82													
83													
84													
85													
86													
87													

LEGEND:
 12.0 CONTACT TIME ~ 6 MIN
 3.3 CONTACT TIME ~ 6 MIN
 OUT OF CONTACT TIME
 IN MINUTES

SUMMARY FOR 5TH & 6TH DAYS:
 MAX GAP TIME
 = 121.6 MIN (INCLUDING CONTACTS ≥ 3 MIN)
 = 134.8 MIN (BETWEEN CONTACTS ≥ 6 MIN)
 = 88
 = 66
 = 709.3 MIN
 = 610.6 MIN

TOTAL NO. OF CONTACTS
 NO. OF CONTACTS > 6 MIN
 TOTAL CONTACT TIME
 CONTACT TIME > 6 MIN

LAST CONTACT OF 6TH DAY

TABLE 7 (CONT'D)
MSFN COVERAGE FOR SKYLAB (235 NM ALTITUDE, 50° INCLINATION) (9° MASKING)

REV	CRO	GWM	HSK	HAW	GDS	TEX	MIL	BDA	SAN	CYI	ACN	CYI	MAD
87	30.7	8.8	11.7	8.6	3.0	8.8		15.7				8.2	
88			4.9	15.2	5.3	6.7	3.9	4.1	0.2	8.7	7.2	7.1	6.2
89			4.5	8.6				16.2					3.7
90	4.7	9.2	4.1	18.4				10.7	4.3				3.7
91					5.3	13.6			8.8				3.7
92					6.4				6.3				3.7
93					8.4			12.5					3.7
94									3.5	9.6	8.5		3.7
95									8.1				10.5
96	27.3	6.3	6.3	3.6		30.7			8.0				12.5
97	34.5		8.8			21.9		6.1					7.0
98	3.7		6.3			35.2		8.7					7.4
99	4.5	4.0	4.2			30.7		14.2					8.7
100	36.8		5.9	21.6		9.1							
101			8.6	12.1	8.2	6.2		3.7	4.2	8.1	2.0	3.5	3.7
102			5.5	13.7	6.8	5.6	4.2	8.4		8.3		8.5	3.7
103	8.3	3.7	8.0			5.4		10.9					
104	6.6	6.9	6.3										
105						14.7							
106						6.0			8.7				
107				4.7					7.1				
108				8.7									
109													
110													
111	6.9					31.5			7.6	7.5	7.9		9.4
112	34.6	7.7				30.5			8.6		6.0	1.3	12.8
113	34.6		8.6			36.6		3.1					6.8
114	8.6	1.5	6.2			31.0		11.7					7.3
115	6.1	3.7	4.6			37.9		14.4					6.8
	34.8		5.3	24.3		9.4							7.5

LAST CONTACT OF 8TH DAY

LEGEND:
 12.0 CONTACT TIME > 6 MIN
 3.3 CONTACT TIME < 6 MIN
 OUT OF CONTACT TIME
 IN MINUTES

SUMMARY FOR 7TH & 8TH DAYS:
 MAX GAP TIME
 = 121.5 MIN (INCLUDING CONTACTS ≥ 3 MIN)
 = 134.6 MIN (BETWEEN CONTACTS ≥ 6 MIN)
 = 96
 = 74
 = 711.7 MIN
 = 607.7 MIN
 TOTAL NO. OF CONTACTS
 NO. OF CONTACTS > 6 MIN
 TOTAL CONTACT TIME
 CONTACT TIME > 6 MIN

TABLE 7 (CONT'D)

MSFN COVERAGE FOR SKYLAB (235 NM ALTITUDE, 50° INCLINATION) (3° MASKING)

REV	CRO	GWM	HSK	HAW	GDS	TEX	MIL	BDA	SAN	CYI	ACN	CYI	'MAD
116	START 9TH DAY → 8.3		7.4	6.2									
117			7.8	4.7									
118	7.6	6.2	6.8										
119	7.8	5.5	7.6										
120													
121													
122													
123													
124													
125													
126													
127													
128													
129													
130													
131													
132													
133													
134													
135													
136													
137													
138													
139													
140													
141													
142													
143													
144													
145													

LEGEND:

12.0 CONTACT TIME > 6 MIN

3.3 CONTACT TIME < 6 MIN

OUT OF CONTACT TIME IN MINUTES

LAST CONTACT OF 10TH DAY

SUMMARY FOR 9TH & 10TH DAYS

MAX GAP TIME = 135.5 MIN (INCLUDING CONTACTS ≥ 3 MIN)

TOTAL NO. OF CONTACTS = 218.0 MIN (BETWEEN CONTACTS ≥ 6 MIN)

NO. OF CONTACTS > 6 MIN = 86

TOTAL CONTACT TIME = 680 MIN

CONTACT TIME > 6 MIN = 626.6 MIN

TABLE 7 (CONT'D)
MSFN COVERAGE FOR SKYLAB (235 NM ALTITUDE, 50° INCLINATION) (3° MASKING)

REV	CRO	GWM	HSK	HAW	GDS	TEX	MIL	BDA	SAN	CYI	ACN	CYI	MAD
145	START 11TH DAY												
146	5.1	32.0	11.6	8.7	6.0	6.0	10.0	6.4	3.8	4.6	7.6	8.0	26.3
147	8.8	4.4	16.7		3.9	3.7	14.4		9.3			5.9	23.7
148												82.5	
149													
150													
151													
152													
153													
154													
155													
156													

END OF 156 REVOLUTIONS, APPROX 10.8 DAYS
COVERAGE PATTERN REPEATS BEYOND THIS POINT

SUMMARY FOR THE 11TH DAY
MAX GAP TIME

= 121.7 MIN (INCLUDING CONTACTS ≥ 3 MIN)
= 135.1 MIN (BETWEEN CONTACTS ≥ 6 MIN)

TOTAL NO. OF CONTACTS
NO. OF CONTACTS > 6 MIN
TOTAL CONTACT TIME
CONTACT TIME > 6 MIN

= 36
= 27
= 285.2 MIN
= 234.3 MIN

LEGEND:

12.0 CONTACT TIME > 6 MIN
3.3 CONTACT TIME < 6 MIN
6.0 OUT OF CONTACT TIME
IN MINUTES

These TV coverages were summarized and tabulated in Table 8 using a reference launch of 3:00 PM (ET) on July 19, 1972. The Tables provide an overview of TV coverages possible from the two complexes and indicate an average of 80 min./day. BDA was eliminated from the U. S. complex of stations since it is not equipped for real-time TV transmission to the U. S. About 22 of these contacts occur during hours of darkness at the Cape and the remainder (50) during daylight hours at the Cape. Complex A, consisting of GDS, TEX, and MIL, had a total of 46 contacts over the 10.8 day span and Complex B, consisting of CYI and MAD, had 26 contacts.

IV. SKYLAB MSFN SUPPORT CAPABILITIES

This section presents an estimate of MSFN support capabilities in the Skylab era. A survey was made of existing ground/space communications and tracking capabilities as presented in references 4 through 8.

In addition, discussions were held with cognizant personnel of the Manned Flight Engineering Division at GSFC on or about May 7, 1970, concerning future planning for the Skylab B era as known at that time. The reference-derived data on MSFN capabilities was then modified by the additional information obtained from the discussions and is presented as an estimate of the support capabilities for Skylab B.

Subsequent to the completion of the estimated support capabilities a Planning Document (X-834-70-107) entitled "Evaluation of MSFN Support Coverage, Capabilities and Constraints for the Skylab Program", dated April 1970, was received from the GSFC.

4. MSFN Equipment Allocations Handbook (MG-403, Parts I and II. Published by GSFC. Revised April 1, 1969.

5. Program Support Requirements Apollo - Saturn V
Published by OMSF, Headquarters NASA. Revision 18 dated August 29, 1969.

6. Space Tracking and DATA Acquisition Network Handbook (X-530-67-304), Published by GSFC July 1967.

7. Proceedings of the Apollo S-Band Technical Conference (NASA SP-87), Published by NASA, 1965.

8. Preliminary MSFN Support Plan for ERTS A&B (X-834-69-529)
Published by GSFC. December 1969.

TABLE 8
ILLUSTRATIVE PAO TV COVERAGE FOR SKYLAB I
(REFERENCE LAUNCH: 3:00 PM (ET), 7/19/72)

COVERAGE				COMPLEX	
DATE	REV	START (ET)	DURATION (MIN)	A	B
7/19	1	4:35 PM	10.6	X	
	5	11:07 PM	15.6	X	
	6	00:44 AM	13.4	X	
	12	9:12 AM	12.2		X
	13	11:17 AM	12.3		X
7/20	14	2:19 PM	9.4	X	
	15	3:54 PM	10.9	X	
	16	5:29 PM	8.7	X	
	19	10:26 PM	15.4	X	
	20	00:03 AM	14.2	X	
7/21	26	08:58 AM	11.3		X
	27	10:35 AM	12.6		X
	29	3:16 PM	11.3	X	
	30	4:48 PM	9.3	X	
	31	5:10 PM	7.4		X
7/22	33	9:50 PM	9.3	X	
	34	11:21 PM	15.0	X	
	35	2:39 AM	10.8	X	
	40	8:17 AM	9.2		X
	41	9:53 AM	12.9		X
7/23	43	2:31 PM	14.4	X	
	44	4:07 PM	9.7	X	
	48	10:40 PM	15.4	X	
	49	00:17 AM	12.1	X	
	55	9:11 AM	13.0		X
7/24	56	10:51 AM	10.4		X
	57	1:50 PM	11.3	X	
	58	3:26 PM	9.4	X	
	62	9:59 PM	15.6	X	
	63	11:36 PM	12.8	X	
7/25	69	8:30 AM	12.8		X
	70	10:09 AM	11.3		X
	71	1:09 PM	10.9	X	
	72	2:45 PM	10.7	X	
	73	4:43 PM	8.6		X

LEGEND: COMPLEX A : U.S. (GDS, TEX, MIL)
B : CYI, MAD

TABLE 8 (CONT'D)
ILLUSTRATIVE PAO TV COVERAGE FOR SKYLAB I
(REFERENCE LAUNCH: 3:00 PM (ET), 7/19/72)

COVERAGE				COMPLEX	
DATE	REV	START (ET)	DURATION (MIN)	A	B
7/27	115	2:17 PM	9.4	X	
	116	2:40 PM	7.5		X
	119	8:50 PM	15.3	X	
	120	10:27 PM	11.6	X	
7/28	125	5:38 AM	8.9		X
	126	7:21 AM	12.9		X
	127	9:02 AM	9.9		X
	128	12:00 PM	11.4	X	
	129	1:35 PM	9.5	X	
	133	8:08 PM	15.5	X	
	134	9:45 PM	12.5	X	
	140	6:40 AM	12.9		X
7/29	141	8:19 AM	10.9		X
	142	11:19 AM	11.1	X	
	143	12:54 PM	10.7	X	
	147	7:27 PM	14.4	X	
	148	9:04 PM	13.0	X	
	153	5:56 AM	12.7		X
7/30	154	7:37 AM	11.6		X
	156	10:38 AM	10.5	X	

COVERAGE				COMPLEX	
DATE	REV	START (ET)	DURATION (MIN)	A	B
7/24	76	9:17 PM	15.3	X	
	77	10:54 PM	13.2	X	
7/25	83	7:49 AM	12.5		X
	84	9:27 AM	11.9		X
	85	12:28 PM	10.1	X	
	86	1:04 PM	10.7	X	
	90	8:36 PM	15.6	X	
	91	10:13 PM	13.6	X	
7/26	97	6:58 AM	10.5		X
	98	8:45 AM	12.5		X
	100	11:48 AM	11.2	X	
	101	2:58 PM	9.1	X	
	104	8:00 PM	9.5	X	
	105	9:31 PM	14.7	X	
7/27	111	6:27 AM	9.4		X
	112	8:03 AM	12.8		X
	114	12:41 PM	11.4	X	

LEGEND: COMPLEX A : U.S. (GDS, TEX, MIL)
B : CYI, MAD

Comparison of the locally derived information on MSFN capability with that contained in this document showed the two to be essentially the same. The Skylab MSFN stations were identical except for the inclusion of the "Vanguard" tracking ship by GSFC. There were discrepancies between the planning document and the locally derived estimate in the number of different VHF receive links and in the number and type of magnetic tape recorders; however, it was understood from the discussions with Engineering Division personnel that these numbers are still quite flexible. The planning document also included one more PCM decommutator at both the Bermuda and Merritt Island stations than was indicated by the cognizant personnel. In addition, the planning document implies that the Santiago station will be equipped as a dual S-band station whereas the discussions with GSFC personnel indicated that this decision had not yet been made. Other than these items there is almost exact agreement between the locally derived estimate and the planning document with respect to the MSFN support capabilities.

The locally derived estimate of MSFN support capabilities for Skylab II are presented in Tables 9 and 10. With the exception of Santiago all are stations of the present MSFN. Santiago is a STADAN station which will be converted to a MSFN station with the addition of MSFN support equipment currently located at the Grand Bahama Island MSFN station.

Table 9 summarizes the capabilities of each of the stations with respect to major ground/space systems. Although the Skylab A vehicle will not be equipped with C-band radar transponder the cross-sectional area of the Skylab vehicle will permit skin-tracking if needed. Therefore, C-band capability has been included. Although it is presently planned that the present VHF telemetry band (240 to 260 MHz) will be vacated by NASA by 1975, with the use of down frequency converters and/or modification of "front-end" tuners it will be possible to utilize the existing VHF receivers within the frequency range from VHF to S-band.

Planned modifications ⁽⁹⁾ of the USB Systems will provide full receive and track capability in the 2200 to 2300 MHz band including auto-track capability when operating in the non-coherent wideband FM or TV mode. The real-time data handling capabilities of the stations are limited by the number of decommutators at each station. It is planned that each station will be equipped with

9. "Evaluation of MSFN Support Converges, Capabilities and Constraints for the Skylab Program", X-834-70-107, GSFC, April 1970.

TABLE 9
MSFN STATION CAPABILITIES

	ACN	AGO	BDA	CRO	CYI	GDS	GWM	HAW	HSK	MAD	MIL	TEX
C-BAND RADAR	X		X	X	X			X			X	
UHF COMMAND	X		X	X	X		X	X			X	X
VHF VOICE	X	X	X	X	X	X	X	X	(X)	(X)	X	X
VHF TELEMETRY ^a	X	X	X	X	X		X	X			X	X
VHF ANTENNAS	X	X	X	X	X	X	X	X	(X)	(X)	X	X
(MASER						X			X	X		
COOLED PARAMP	X			X		X	X	X	X	X		
PARAMP		X	X		X						X	X
RECEIVING SYST	4	2	4	4	4	4	4	4	4	4	4	4
30' ANTENNA	1	1	1	1	1		1	1			(2)	1
85' ANTENNA						1			1	1		
DEMODULATOR	2	1	2	2	2	2	2	2	2	2	(3)	2
DECOMMUTATOR ^b	X	X	X	X	X	X	X	X	X	X	X	X
MAGNETIC TAPE RECORDERS	3	3	3	3	4	1	2	2	1	1	3	3
VOICE	1		4	3	3		1	3	1	2	2	4
NARROW BAND	3	3	4	3	4	5	3	4	5	5	4	4
WIDE BAND	1	1	1	1	1	2	1	1	3	2	3	1
TELEVISION VIDEO												

NOTES: () FUTURE PLANNING

a. 7-8 VHF LINKS PER STATION

b. 4 PER STATION EXCEPT MIL WHICH HAS 6

TABLE 10
MSFN RECORD CHANNEL/BANDWIDTH AVAILABILITY

VOICE	ACN	AGO	BDA	CRO	CYI	GDS	GWM	HAW	HSK	MAD	MIL	TEX
# CH.	30	30	30	30	44	14	16	16	14	14	30	30
N. B.			14	28							7	
			28	14	14			14				28
			14		14			14		14		14
	14				14	14	14	14	14	14	14	14
TOTAL	2.5		5.4	6.4	4.0	2.5	2.5	4.0	2.5	2.6	4.2	5.4
# CH.			14	14	14			14			14	14
W. B	28	28	28	14	28	56	28	28	56	56	28	28
	14	14	14	14	14	14	14	14	14	14	14	14
TOTAL	42.0	42.0	63.0	56.0	63.0	56.0	42.0	63.0	56.0	56.0	63.0	63.0
# CH.	1	1	1	1	1	2	1	1	2	2	1	1
T. V.*									1		2	

* TWO VOICE CHANNELS WITH EACH VIDEO CHANNEL

at least four programmable decommutators (three prime and one backup) each of which has a data handling rate 1 megabit per second (Mbps) maximum or a maximum of 4 Mbps per station. Stations are equipped with magnetic tape recorders for voice, data, and television video as shown.

Table 10 presents the recording channel capacity and the total recording bandwidth (in MHz) of each of the categories of recorders.

Figure 1 depicts the general flow of information and data through a typical station.

For the purpose of sizing the capacity of the MSFN for receiving bulk experiment data from Skylab B, the capability listed in Table 11 is used. The major limitation is the IF bandwidth of the four receiving channels which are 5 MHz each. This is sufficient to accommodate a 5 Mbps digital signal with appropriate modulation technique. It is assumed that the digital data will be recorded on tape following the IF stage instead of decommutated in real-time. The tape will then be transported to the mission control center.

V. THE USE OF INTELSAT IV SATELLITES FOR DIRECT RELAY

The feasibility of using Intelsat satellites as a direct communications relay between a manned space vehicle and Mission Control Center has been studied previously in References 10 and 11. The specific application of using Intelsat IV as a direct relay for Skylab missions was analysed in Reference 12. A system definition contract of designing a communications terminal on the Skylab spacecraft for the Intelsat IV direct relay was done by Hughes Aircraft Company for NASA, and the final report was published in February 1970⁽¹³⁾.

10. R. K. Chen, "The Use of Intelsat Satellites for Direct Voice Communications with Manned Space Vehicles", Bellcomm TM-68-2034-15, September 30, 1968.

11. R. K. Chen, "The Use of Intelsat Satellites for Direct Voice and Data Communications with Manned Space Vehicles", Bellcomm TM-69-2034-2, March 31, 1969.

12. R. K. Chen, "AAP Terminal Requirements Using Intelsat IV for Communications Relay", Bellcomm MFF-6909061, September 24, 1970.

13. "An Apollo Applications Program Data Relay Terminal Design Study", Hughes Aircraft Company Report No. SSD-00058R, February 1970.

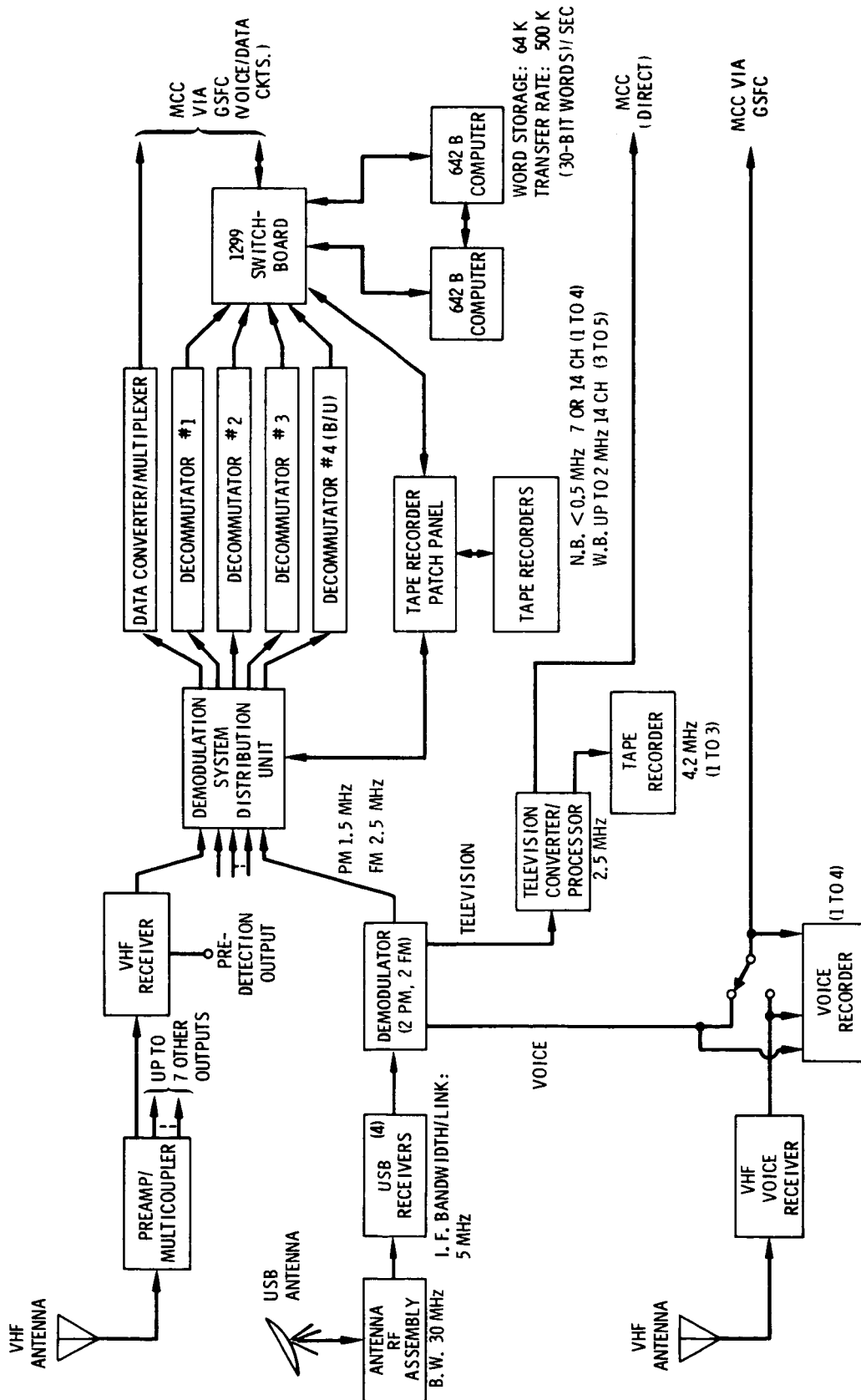


TABLE 11
SKYLAB MSFN RECEIVING CAPABILITY
(S-BAND)

AVAILABLE FREQUENCY	4 (2270 TO 2300 MHz)
BANDWIDTH (RF)	4 — 5 MHz CHANNELS
TELEVISION VIDEO BANDWIDTH	2.5 MHz
TELEVISION RECORDER BANDWIDTH	4.2 MHz
DECOMMUTATOR	4 — 1.0 MBPS CHANNELS
TAPE RECORDERS	
NARROW-BAND (LESS THAN 250 KHz BW/CHANNEL)	14 TO 56 CHANNELS/STATION
WIDE-BAND (UP TO 2 MHz BW/CHANNEL)	42 TO 70 CHANNELS/STATION
VIDEO (3 TO 4.2 MHz/RECORDER)	1 TO 3 RECORDERS/STATION

The ground rules given to Hughes for the study is shown in Table 12, and the areas studied by Hughes is shown in Table 13. The study result is a proposed terminal system by Hughes given in Table 14. One of the overriding desires at the time of the Hughes study was to have the terminal integrated into the Skylab A mission; therefore, the schedule and the cost had to be minimized. This resulted in using subsystems and components that are either space qualified or of proven development status. No attempt was made to minimize the overall weight of the system as it was believed that weight was not a severe constraint for the Skylab A dry workshop.

A question that has been asked often concerning the Intelsat IV relay is: "Can we send television through the satellite relay link?", or "can we send X number of bits per second through the relay link?" The answer is one can send anything through the satellite limited to a 40 MHz of RF bandwidth if you put a large enough terminal on the spacecraft. To assist those who are interested in approximate sizing of the terminal, Figure 2 is provided.

There are several potential problems that need further analysis on the implementation of a Intelsat terminal on the Skylab:

1. blockage of the radiator mounted on the bottom of the OWS if the terminal antenna fails to deploy,
2. possible RF interference to terrestrial users on the common carrier frequencies, and
3. Adaptability of the antenna steering design to the artificial G experiment.

VI. RECEIVING SYSTEM PROPOSED FOR EARTH RESOURCES TECHNOLOGY

SATELLITE (ERTS)

Two ERTS (A and B) are being planned for launching in 1972 and 1973. These satellites would be the first dedicated developmental operational satellites for the purpose of surveying earth resources. The Earth Resources Experiment Package (EREP) that will be carried on Skylab missions would be a continuation in the technology development of earth resources surveying systems. Since the ERTS missions precede Skylab missions, it is natural to ask if the ground support systems planned for ERTS would be of any value to the support of Skylab missions.

TABLE I2
GROUND RULES FOR HUGHES STUDY

- INTELSAT IV SATELLITE
- USING ONE ENTIRE INTELSAT IV TRANSPONDER (12 TRANSPONDERS/SATELLITE)
- USING INTELSAT IV EARTH COVERAGE ANTENNAS
- COMMUNICATIONS REQUIREMENTS
 - TWO-WAY VOICE
 - 1 KBPS UPLINK
 - 72 KBPS DOWNLINK (MAX)
- SKYLAB ORBITAL ATTITUDE - SUN INERTIAL MODE OR POP MODE
- REACTION WITH SKYLAB - SLEWING OF THE ANTENNA SHALL NOT IMPOSE A TORQUE ON THE SKYLAB IN EXCESS OF 50 FT-LB, NOR SHALL THE INTEGRATED TORQUE ON THE SKYLAB EXCEED 500 FT-LB/SEC
- ONE YEAR ORBIT LIFE
- SELF-CONTAINED THERMAL CONTROL
- 250 WATT PRIME POWER MAX, 25-30 VDC
- WEIGHT NOT SEVERELY CONSTRAINED

TABLE 13
"AN APOLLO APPLICATIONS PROGRAM DATA RELAY TERMINAL DESIGN STUDY"
HUGHES CONTRACT FINAL REPORT, FEBRUARY, 1970

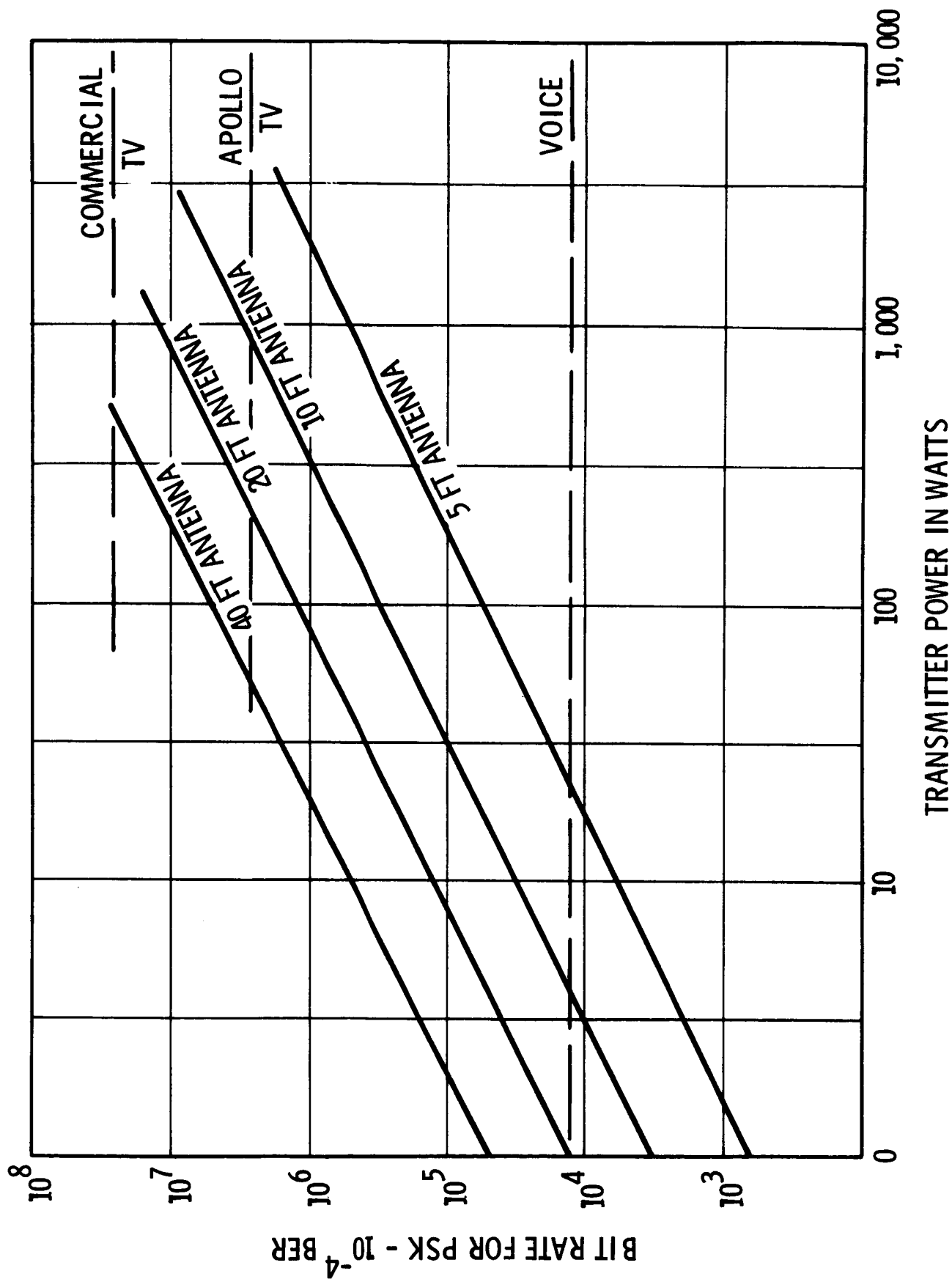
AREAS STUDIED

- COMMUNICATION LINK ANALYSIS
- MODULATION AND MULTIPLEXING TECHNIQUES
- ANTENNA SYSTEM AND ANTENNA FEED
- ANTENNA RF TRACKING ANALYSIS
- ACQUISITION ANALYSIS
- POWER AND WEIGHT ESTIMATES
- TELEMETRY, COMMAND, AND MANUAL CONTROL
- THERMAL DESIGN
- CCIR INTERFERENCE CRITERION AND SPREAD SPECTRUM
- COST ESTIMATE

TABLE 14
HUGHES PROPOSED SYSTEM

ANTENNA SIZE	15 FT. PARABOLOID, CASSEGRAINIAN FEED
TRANSMITTER POWER	20 WATT TWT
RECEIVER SYSTEM NOISE TEMPERATURE	1120° K
TOTAL SYSTEM WEIGHT	750 LBS
PRIME POWER REQUIRED	160 WATT (AVE)
ANTENNA TRACKING	RF, TIME SHARED MONOPULSE
ANTENNA ACQUISITION	10° X 10° AUTOMATIC SCANNING ATM COMPUTER ASSIST FOR INITIAL ACQUISITION
THERMAL PROTECTION	PASSIVE
OPERATIONAL LIFE	ONE YEAR
UPLINK	SIMULTANEOUS VOICE AND 1 KBPS UP-DATA
DOWNLINK	SIMULTANEOUS VOICE AND 72 KBPS TELEMETRY
MODULATION	TLM CHANNEL A 72 KBPS
	B 51.2 KBPS
	C 1.6 KBPS + 4.0 KBPS + 5.12 KBPS + 5.12 KBPS + 5.76 KBPS
	UPLINK - SINGLE CARRIER FM DOWNLINK - TWO CARRIER FM

FIGURE 2
DOWN-LINK S/C TERMINAL REQUIREMENT
USING INTELSAT IV RELAY



The information in this section is extracted from Reference 14, which is a planning document on ground support system for ERTS.

Three primary payloads planned for ERTS are:

1. Multispectral return beam vidicon (RBV) TV camera system,
2. Multispectral point scanner (MSPS), and
3. Data collection system (DCS).

The first two payloads, which are the wideband data generators, are of special interest to the Skylab mission support as their functions closely resemble the Multispectral Photography Facility (S-190) and the 10-band Multispectral Scanner Assembly (S-192) experiments planned for Skylab missions. A brief summary of RBV and MSPS is shown in Table 15. Although it is indicated on Table 15 that the data from RBV may be recorded on ERTS and played back subsequently, this feature is still uncertain depending on the feasibility of incorporating a reliable wideband video recorder on the spacecraft. Without the onboard recorder, the present planning is to send the wideband data in real-time to three ground receiving stations located in the U. S. The three stations are: (1) the MSFN station at Texas, (2) the STADAN station at Fairbanks, Alaska, and (3) Network Testing and Training Facility (NTTF) located at GSFC. These sites are chosen because their combined coverage would take in all of the North and Central America continent, which would be the prime target for the Earth survey. The coverage area provided by these sites is shown in Figure 3. In order to receive the wideband data from ERTS, the ground station requires modifications and additions to their present configuration. Typically, a modified MSFN USB station with ERTS receiving capability would be similar to that shown in Figure 4. The specific modifications and additions are summarized in Table 16, the estimated cost for the modifications and additions is \$1.42 million per station as given in Reference 14.

14. "Preliminary MSFN Support Plan for ERTS A and B", GSFC Report No. X-834-69-529, December, 1969.

TABLE 15
ERTS A & B PLANNING (REF. 14)

DATA SOURCES

1. RETURN BEAM VIDICON SYSTEM (RBV)

THREE SENSORS, SINGLE VIDEO OUTPUT
100 X 100 NM SCENE, ONE SCENE PER 25 SECONDS
SEQUENTIAL READOUT 5 SECONDS PER SENSORS
4 MHZ TOTAL VIDEO BANDWIDTH, FM ON CARRIER
DIRECT TRANSMISSION ON 2265 MHZ CARRIER OR RECORDED ON
WIDEBAND VIDEO TAPE RECORDER

2. MULTISPECTRAL POINT SCANNER (MSPS)

FOUR SPECTRAL BANDS, 0.5 TO 1.1 MICRONS
SCAN ANGLE $\pm 5.8^\circ$, INSTANTANEOUS FIELD OF VIEW = 230 X 230 FT
SIX DETECTORS PER SPECTRAL BAND, 24 DETECTORS TOTAL
PCM/FM MODULATION, VIDEO BANDWIDTH ≈ 6 MHZ, 14.7 MBPS
DIRECT TRANSMISSION ON 2230 MHZ

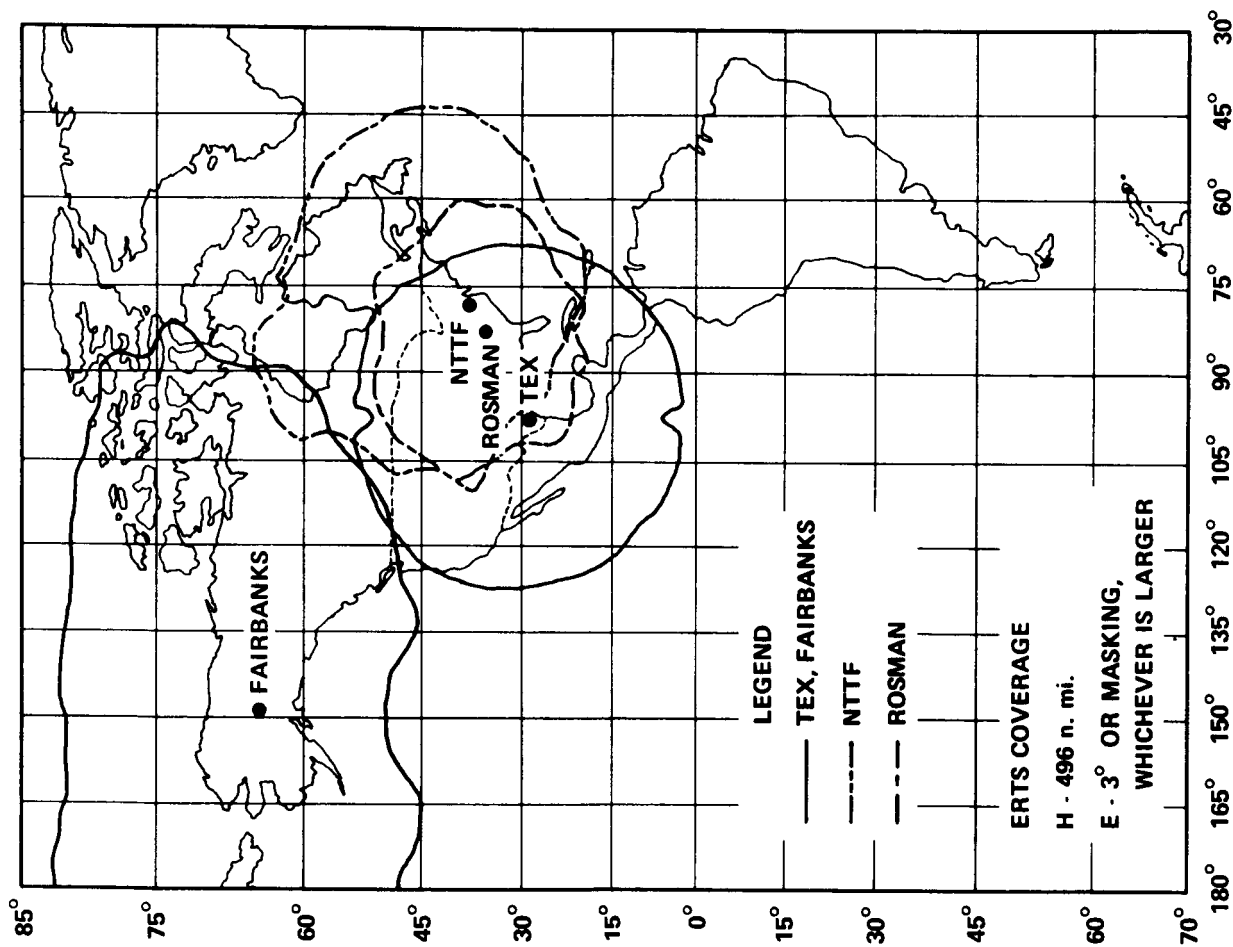
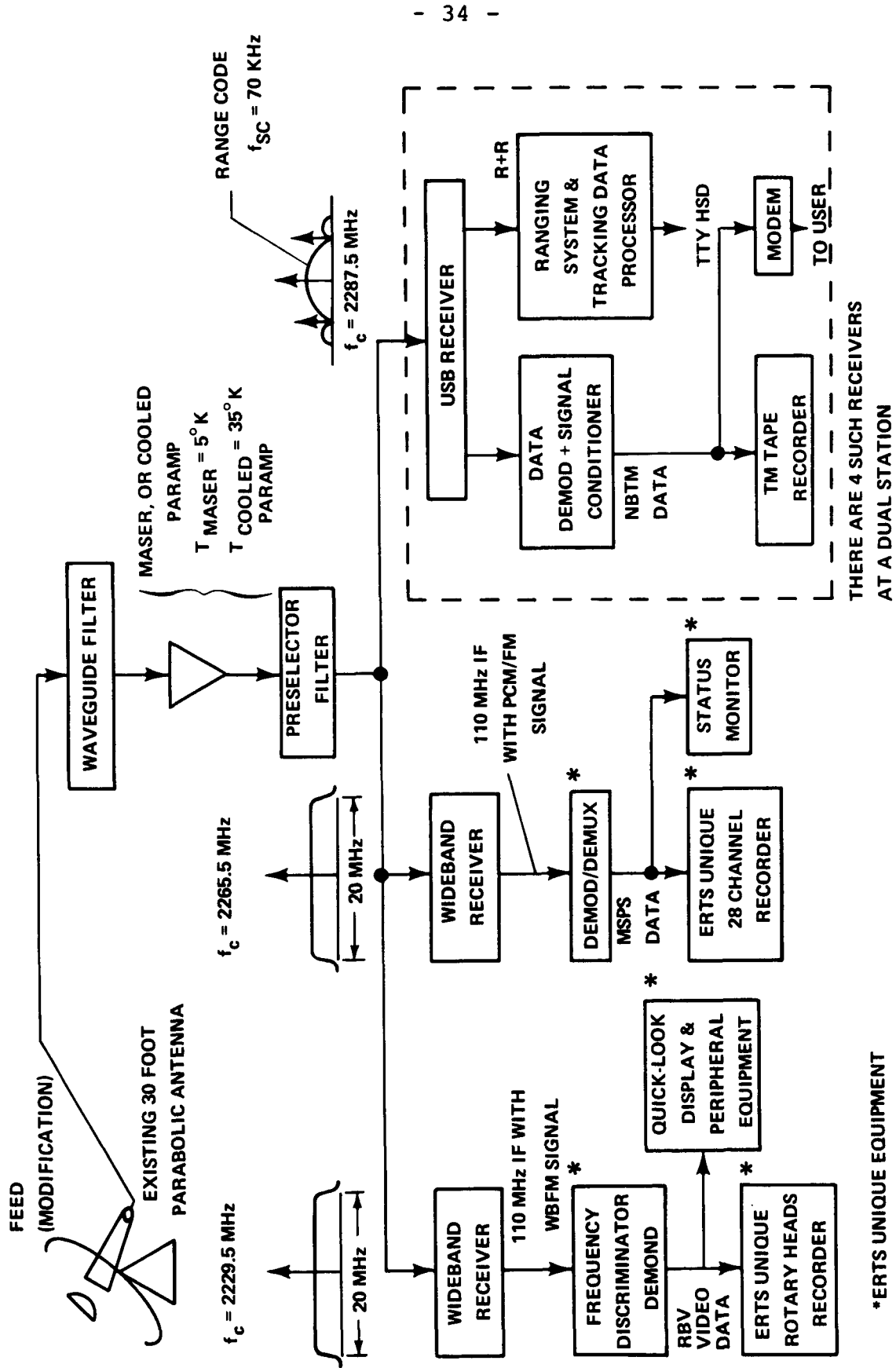


FIGURE 3 - INITIAL STATION COVERAGE FOR ERTS (REF. 14)



*ERTS UNIQUE EQUIPMENT

FIGURE 4 - USB ERTS RECEIVING STATION (REF. 14)

TABLE 16
EQUIPMENT REQUIRED AT THE TEX MSFN STATION TO SUPPORT ERTS
(REF. 14)

SYSTEM	EQUIPMENT
ANTENNA RF	FEED MODIFICATIONS WAVEGUIDE FILTER COOLED PARAMP PRESELECTION FILTER
RECEIVER/ DEMOM	TWO WIDEBAND RECEIVERS (20 MHz RF BANDWIDTH; 110 MHz IF C FREQUENCY) HUGHES A/C DEMOD/DEMULTIPLEXER FOR MSPS DATA WITH 28 CHANNEL RECORDER AND STATUS MONITOR
RECORDERS	BACK-UP 28 CHANNEL RECORDER FOR MSPS DATA TWO ROTARY HEAD TV RECORDERS FOR RBV DATA
DISPLAYS	QUICK-LOOK DISPLAYS FOR RBV DATA (INCLUDING PERIPHERAL EQUIPMENT)
SPARES	WIDEBAND RECEIVERS DEMOM/DEMOM WITH MONITOR RBV DISPLAYS
ADMINISTRATION	CABLING & MISCELLANEOUS INSTALLATION AND TRAINING CONTINGENCIES INCLUDING DOCUMENTATION

ESTIMATED COST = \$1.42 MILLION
INCLUDE COMPLETE REDUNDANCY
FOR ERTS UNIQUE EQUIPMENT

The three planned ERTS stations would not provide complete coverage for North and Central America for Skylab missions. The reasons are:

1. ERTS will be in a higher orbit than Skylab, 496 n.m. instead of 235 n.m., and
2. The ERTS orbit has an inclination angle of 99° compared with the 50° inclination for Skylab.

The first factor reduces the ground station visibility of the Skylab considerably, and the second factor rules out the use of Fairbanks entirely since it is situated too far north (approximately 65° N latitude) to see the Skylab. The end result is that Texas and NTTF would not be able to provide even continental U. S. coverage unless some other station is added to it, such as Goldstone. Figure 5 provides a rough sketch of the coverage provided by Texas, NTTF, and Goldstone. The interesting thing to note on Figure 5 is that when Goldstone is added to the combination, the Texas station provides very little unique coverage for the continental U. S. A computer run was made to determine the coverage provided by the NTTF and Goldstone stations combined, the result is shown in Table 17. Again, only the data from the first 156 revolution (approximately 10.8 days) is given, as the coverage results repeat closely every 156 revolution for the planned Skylab orbit. On the average, these two stations would provide approximately 100 minutes per day of coverage time greater than 5 minutes contact time; furthermore, a large number of contacts are continuous between the two stations or with very small gap time in between. It is obvious that the coverage provided by these two stations compares very favorably with the 300 minutes per day coverage provided by the 12 station configuration of the full Skylab MSFN.

The receiving capability of the ERTS type of modification for Skylab is estimated by making a RF link calculation as shown in Table 18. By assuming a 20 watt transmitter on the Skylab using an omni-directional antenna and including 6 dB total transmitting losses, a carrier-to-noise ratio (C/N) of 18.7 dB in 20 MHz of RF bandwidth can be achieved for the link. Such a link performance could support:

1. a 15 dB C/N frequency modulated television channel (3.4 MHz baseband bandwidth) with a modulation index of 2, which would provide a baseband signal-to-noise ratio (SNR) of 39 dB (peak-to-peak signal to rms noise), and

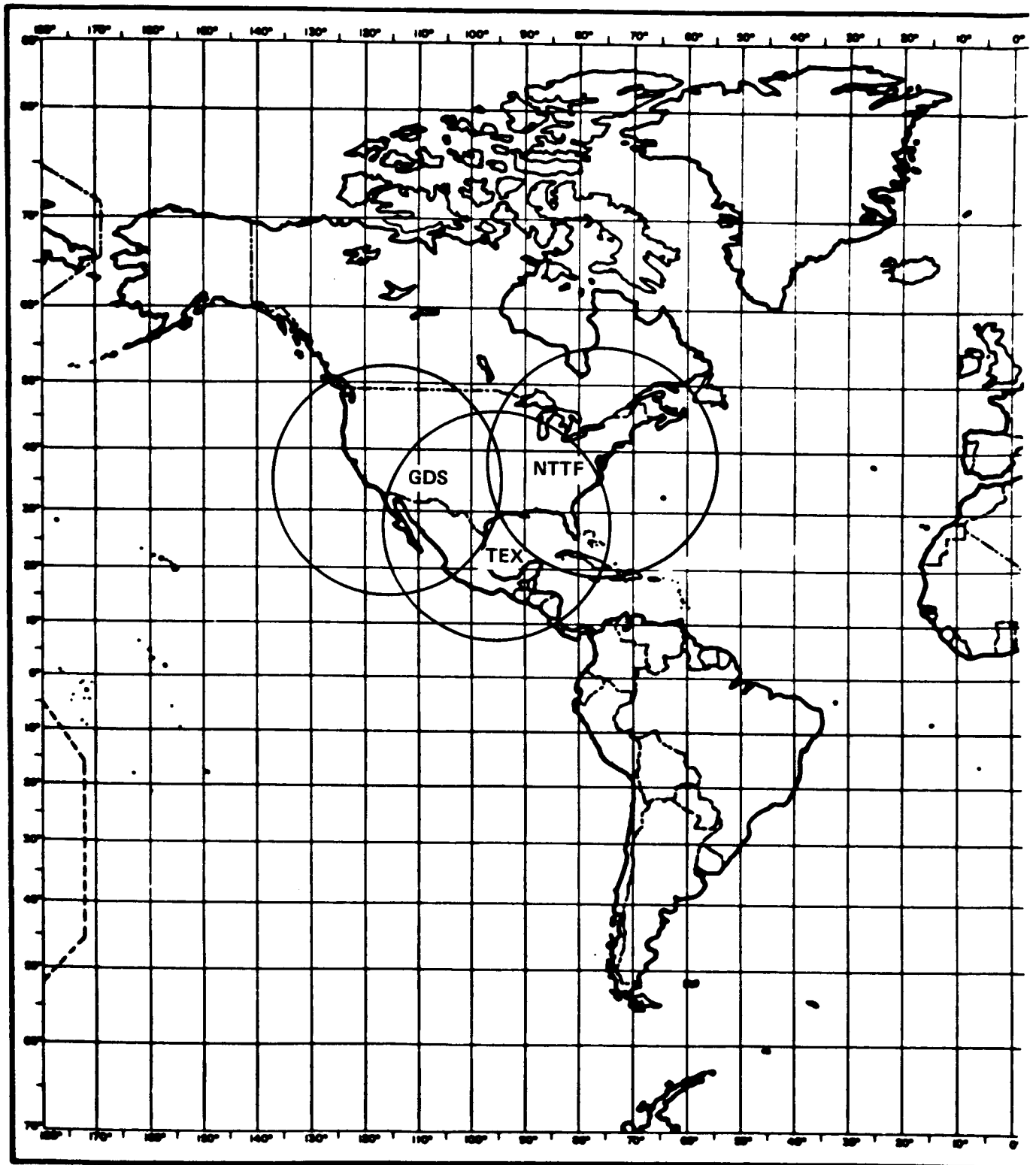


FIGURE 5 - POSSIBLE U. S. STATION COVERAGE FOR SKYLAB II S/C ALTITUDE = 235 NM
GROUND STATION MASKING = 3° INCLINATION = 50°

TABLE 17
POSSIBLE EREP COVERAGE FOR SKYLAB II (235 N.M., 60° INCLINATION) (3° GROUND STATION MASKING)

REV	GDS	NTTF	GDS	NTTF	GDS	NTTF	GDS	NTTF	GDS	NTTF	GDS	NTTF						
1-5	5.3	0.8	9.3	80.3	17.2	7.9	82.5	6.9	1.0	8.3	82.7	5.6	0.6	9.7	87.8	14.6	(8.3)	82.4
5-10	9.6	90.4																
11-15																		
16-20	(9.7)	17.1	(8.1)	82.6	6.8	0.6	8.1	82.7	5.7	0.9	9.5	82.0	(7.0)	15.0	(9.0)	81.6	9.5	90.6
21-25	6.1							712.0										
26-30																		
31-35	6.7	0.6	7.9	82.5	6.1	1.0	8.3	82.2	(6.5)	15.3	(9.4)	81.7	6.9	90.5				
36-40								713.3										
41-45								88.5										
46-50	6.5	1.1	9.0	82.4	(16.1)	15.5	(8.7)	81.6	6.6	1.3	4.8	84.5	9.5					
51-55														713.9				
56-60																		
61-65	(5.8)	15.6	(8.7)	81.7	(8.3)	13.7	(5.7)	83.3	9.7	90.0	8.9	80.4	9.5	0.1	7.7	82.1	7.0	1.1
66-70													4.5					
71-75														714.0				
76-80	(7.8)	14.4	(8.0)	82.5	9.7	90.3			5.3									
81-85																		
86-90	4.9	0.6	9.5	80.2	(9.7)	17.2	(8.0)	82.6	6.8	0.9	8.2	82.7	5.7	0.8	9.5	82.0	(7.2)	14.8
91-95	9.6	90.5							5.8									
96-100																		
101-105	(9.7)	17.1	(8.2)	82.0	6.7	0.8	7.9	82.6	5.9	1.0	9.4	82.1	(8.8)	15.1	(9.2)	81.9	9.3	90.5
106-110	6.5									713.7								
111-115																		
116-120	6.7	0.5	7.8	82.5	6.3	1.0	9.2	82.3	(6.3)	15.4	(9.6)	81.6	6.7	1.9	3.3	85.4	9.4	
121-125								713.4										
126-130																		
131-135	6.8	1.1	8.8	82.6	(5.9)	15.5	(9.7)	81.7	6.6	0.7	5.9	83.8	9.7	90.1				
136-140																		
141-145																		
146-150	5.7	0.3	9.7	81.8	(8.0)	14.0	(7.4)	82.9	9.7	90.2			4.9					
151-155										713.6								
156-159																		

END OF 156 REVOLUTIONS
COVERAGE PATTERN REPEATS
APPROXIMATELY BEYOND THIS POINT

SUMMARY FOR 156 REVS:
MAX GAP TIME

TOTAL NO. OF CONTACTS
NO. OF CONTACTS ≥ 6 MIN
TOTAL CONTACT TIME
CONTACT TIME ≥ 6 MIN

= 809.0 MIN (BETWEEN CONTACTS ≥ 6.0 MIN)
= 714.0 MIN (BETWEEN CONTACTS ≥ 3.0 MIN)
= 122
= 102
= 1122.8 MIN
= 1022.4 MIN

LEGEND:

9.3 CONTACT TIME IN MINUTES
NTTF GAP TIME BETWEEN CONTACTS
(9.7) 17.2 (7.9) (9.7) & (7.9) ARE CONTACT TIMES OF INDIVIDUAL STATIONS. 17.2 IS COMBINED NON-OVERLAPPING TIME OF THE SAME STATIONS
5.3 CONTACT < 6.0 MIN

TABLE 18
SAMPLE SIGNAL MARGIN CALCULATION FOR ERTS STATION LINK

PARAMETER	UNITS	WORST CASE
SPACECRAFT TRANSMITTED POWER	dbm	+ 43 (20w)
SPACECRAFT ANTENNA GAIN	db	0
SPACECRAFT LOSSES	db	- 6
POLARIZATION LOSS	db	0
SPACE LOSS (E = 3°, R = 1040 n. mi.)	db	- 165.9
GROUND ANTENNA GAIN (30 FT.)	db	+ 43.5
GROUND SYSTEM LOSSES	db	- 0.5
GROUND RECEIVED SIGNAL POWER	db	- 85.9
SYSTEM NOISE SPECTRAL DENSITY	dbm/Hz	- 177.6 (128°K)
NOISE POWER IN 20 MHz (73 db)	dbm	- 104.6
C/N IN 20 MHz	db	+ 18.7

2. a 10.5 dB C/N PCM/PM link with 20 megabit/sec of digital data, which correspond to a bit error rate of 10^{-4} .

In summary, ERTS type of MSFN modifications would permit:

1. two simultaneous TV transmissions, or
2. two simultaneous 20 mbps digital data transmissions, or
3. one TV plus one 20 mbps digital data transmission

with 20 watts transmitter and omni-directional antenna on board the Skylab spacecraft. On the average, the coverage time provided by the NTTF and the modified Goldstone stations is 100 minutes per day.

VII. OPTIONS FOR HANDLING SKYLAB EXPERIMENT DATA

Three examples are given as options for handling the bulk experiment data from Skylab II mission:

1. using the 12 MSFN stations without major modifications,
2. adding Intelsat IV relay to the 12 MSFN stations, and
3. adding NTTF to the 12 MSFN stations with Goldstone modified to ERTS type of receiving capabilities.

Although this memorandum is not concerned with the operational data aspect of the Skylab mission, the handling of the operational data does impact the capacities of the network to receive experiment data. In the following, assumptions are made that either one or two RF links are dedicated to the transmission of operational data; furthermore, an RF link for dumping recorded operational data is also allowed except when Intelsat IV relay is used. It is reasoned that when near continuous (85% or more) coverage is available through Intelsat relay, the need for recording operational data would be minimal. The rationale for one operational data link is that an integrated data system would be designed for the Skylab B mission including the CSM data after it is docked to the orbital workshop. The allowance for two operational data links is to exclude the integration of the CSM data to the remaining integrated system in case that the CSM/orbital workshop data interface proves to be impracticable.

It is also well to point out that in the following when the experiment data transmission are matched to the receiving capabilities of network options, no attempt is made to determine the implications of the feasibility or practicability of the necessary implementation on the Skylab spacecraft for the data processing and management. The purpose of this memorandum, as mentioned in the Introduction, is to examine the receiving capabilities of several MSFN configurations; we are addressing the question of "What is possible" in the MSFN data handling capability.

MSFN WITHOUT MAJOR MODIFICATIONS

Assuming that ALSEP support can be scheduled on a non-conflicting basis, each station of the MSFN can receive four S-band links simultaneously. Each link is limited to a 5MHz IF bandwidth which is assumed to be capable of supporting 5 mbps of digital data. It is further assumed that the digital data will be recorded following the IF amplifiers instead of recorded after demodulation and decommutation. The 12 MSFN stations as a whole is assumed to provide 300 minutes/day of coverage time*; out of this coverage time, 80 minutes of television transmission is assumed. With these assumptions, the link assignment is:

1. Mode A - Two operational data links, one operational data dump link, and one television or experiment data dump link.
2. Mode B - One operational link, one operational data dump link, one television or experiment data dump link, and one experiment data dump link.

The receiving capacities for experiment data are:

1. Mode A - 220 channel minutes per day is available, which represents 6.6×10^{10} bits of receiving capability. The receiving capacity matches the combined experiment data requirement of X-ray spectroheliograph (2.2×10^8 bits/day), photoheliograph (2.6×10^{10} bits/day), radar imager (1.6×10^{10} bits/day), and 10-band multispectral scanner (1.6×10^{10} bits/day). The potential return weight saving from these experiments is 440-500 lbs.**

*Coverage time varies on a daily basis as can be seen in Section III, 300 minutes/day is an average number used here for working out the examples.

**The weight range is due to the uncertainty or radar imager experiment.

2. Mode B - 520 channel minutes per day is available, which represents 1.56×10^{11} bits of receiving capability. The receiving capacity matches the combined experiment data requirement listed in Mode A with the addition of metric camera (10^{11} bits/day). The potential return weight saving from these experiments is 506-566 lbs.*

MSFN WITHOUT MAJOR MODIFICATIONS PLUS INTELSAT IV RELAY

The Intelsat IV relay is assumed to be used for the transmission of operational data; in addition it is also assumed that the requirement of recorded operation data is deleted. The net result of having Intelsat IV relay is to free two RF links, which become available to the dumping of experiment data:

1. Mode C - One operational data link, one television or experiment data dump link, and two experiment data dump links.
2. Mode D - One television or experiment data dump link, and three experiment data dump links.

The receiving capacities for experiment data are:

1. Mode C - 820 channel minutes per day is available, which represents 2.5×10^{11} bits of receiving capability. This capability matches that of Mode B, except the transmission of either the metric camera or the multispectral photography (1.44×10^{11} bits/day) data can be considered. The potential return weight saving from these experiments is 506-566 lbs.*
2. Mode D - 1120 channel minutes per day is available, which represents 3.3×10^{11} bits of receiving capability. In this mode, the data from all six experiments considered, which have a total of approximately 3.0×10^{11} bits/day, can be accommodated. The potential return weight saving is 542-602 lbs.*

*The weight range is due to the uncertainty of radar imager experiments.

MSFN WITH ERTS TYPE MODIFICATION PLUS NTTF

The NTTF station at GSFC is added to the MSFN; in addition, ERTS type of receiving capability is also added to the Goldstone station. The net effect of these changes is increasing the coverage time by 100 minutes per day, which represents the following added receiving capacities over Modes A and B:*

- (1) two television channels for 100 minutes per day, or
- (2) two 20 mbps channels, (2.4×10^{11} bits per day), or
- (3) one television channel for 100 minutes per day plus one 20 mbps channel (1.2×10^{11} bits per day).

There are several combinations of network usage that can be considered with this configuration:

Mode E - An interesting idea is to consider the dumping of experiment data to NTTF and modified Goldstone stations exclusively. The advantage is having all experiment data collected over two stations in the U. S. rather having them scattered over 12 stations around the world. Under this assumption, six S-band links are possible (four MSFN links and two ERTS links). These six links would have a combined capability of receiving 60 mbps of data or, on a daily basis, 3.6×10^{11} bits, which is sufficient to receive all six experiment data considered. The potential return weight return saving is 542-602 lbs.**

Mode F - The two solar astronomy experiments, as seen in Table 4, could use a vidicon sensor rather than using film. The advantage of using vidicon is more than the saving of 180 lbs of return weight, as it would also eliminate the need of carrying more film on the return visits to the Skylab plus the saving on the shielding weight for film storage onboard.

*Actually, Goldstone, with its 85 ft. diameter antenna, has 7 times larger receiving capacity than the proposed ERTS type of receiving stations, which are equipped with 30 ft. diameter antennas.

**The weight range is due to the uncertainty in radar imager experiment.

Of course, a complete tradeoff must be made in order to determine if a vidicon system plus a video tape recorded is better or worse than the proposed film system. Nevertheless, it is possible to put the data from two solar experiments on a single video channel using frequency division multiplex (FDM) and frequency modulates a single RF link and transmits them exclusively to the NTTF and modified Goldstone stations. This would still allow the two stations to receive 2.4×10^{11} bits per day of digital data which is sufficient to receive all other experiments except the multispectral photography. The potential return weight saving is 506-566 lbs.*

*The weight range is due to the uncertainty in radar imager experiment.

VIII. SUMMARY

In general, considerable capacity exists in the MSFN (without major modification) for the reception of experiment data from Skylab programs. With the addition of Intelsat IV relay or ERTS type of modifications at two stations, NTTF and Goldstone, considerably more capacity is added to the network. A summary of the potential return weight savings is given in Table 19.

The advantage of having Intelsat IV relay is the near continuous access (85% or more) of an operational link for the mission. The advantage of using NTTF and ERTS type of modification at Goldstone is the collection of all experiment data at these two sites in the U. S. rather having it scattered at 12 MSFN sites around the world.

This memorandum does not include all possible modifications of MSFN and, therefore, the ultimate desirable capacity of the network and its configuration. It does indicate several feasible ways of transmitting bulk Skylab experiment data to Earth over radio frequency links other than using tape and film to be brought back on the CSM.



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TABLE 19
SUMMARY - POTENTIAL RETURN WEIGHT SAVINGS

	OPERATIONAL LINK	EXPERIMENT DATA DUMP (BITS/DAY)	WEIGHT SAVING		EXPERIMENTS TRANSMITTED
			FILM *	TAPE	
MSFN WITHOUT MAJOR MODIFICATIONS	MODE A 2	6.6×10^{10}	240-300	200	4
	MODE B 1	1.56×10^{11}	306-366	200	5
	MODE C 2	2.5×10^{11}	306-366	200	5
MSFN WITHOUT MAJOR MODIFICATIONS PLUS INTELSAT IV	MODE D 1	3.3×10^{11}	342-402	200	ALL SIX
	MODE E **	3.6×10^{11}	342-402	200	ALL SIX
MSFN PLUS NTTF WITH ERTS MODIFICATION AT GDS	MODE F **	2.4×10^{11} PLUS ONE TV LINK	306-366	200	5

80 MINUTES/DAY OF TV TRANSMISSION IS INCLUDED IN ALL CASES

* THE WEIGHT RANGE IS DUE TO THE UNCERTAINTY IN RADAR IMAGES EXPERIMENT

** IN THESE MODES, EXPERIMENT DATA ARE DUMPED TO NTTF AND GDS STATIONS ONLY